Energy 239 (2022) 122106

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

How sensitive is a carbon-neutral power sector to climate change? The interplay between hydro, solar and wind for Portugal

Patrícia Fortes [a, *], Sofia G. Simoes [b, **], Filipa Amorim [b], Gildas Siggini [c], Valentina Sessa [c], Yves-Marie Saint-Drenan [d], Sílvia Carvalho [e], Babar Mujtaba [f], Paulo Diogo [f], Edi Assoumou [c]

[a] CENSE — Centre for Environmental and Sustainability Research Energy and Climate, NOVA School of Science and Technology, NOVA University Lisbon, Portugal
[b] LNEG — National Laboratory for Energy and Geology, Portugal
[c] Centre de Mathématiques Appliquées (CMA), MINES ParisTech, Sophia Antipolis, France
[d] OIM, MINES ParisTech, Sophia Antipolis, France
[e] CCIAM, Faculdade de Ciências, Universidade de Lisboa, Portugal
[f] MARE, NOVA School of Science and Technology, NOVA University Lisbon, Portugal

ARTICLE INFO

Article history:
Received 2 April 2021
Received in revised form
17 September 2021
Accepted 18 September 2021
Available online 24 September 2021

Keywords:
Power system
Future climate variability
Renewables
Technologies capacity factors
Carbon neutrality
TIMES model

ABSTRACT

Climate change will impact renewable resources and electricity demand, usually not jointly considered when designing future decarbonized power systems. This paper assesses how sensitive the Portuguese carbon-neutral power sector is to climate change by 2050 and what are the implications for the formally approved Portuguese Carbon Neutrality Roadmap.

The future capacity factors for wind, solar and hydropower and electricity demand response to temperature are estimated for 22 climate projections along the Representative Concentration Pathway 4.5 and 8.5. The eTIMES_PT optimization model is used to assess its combined impact on the cost-optimal configuration of the power sector by 2050. Results show that climate change lowers hydropower generation by 20% (in median terms). Improving spatial and temporal resolution and including future climate patterns, results also in lower cost-effectiveness of solar photovoltaic vis-à-vis the Carbon Neutrality Roadmap. While future climate does not impact onshore wind production, offshore wind power generation is positively affected, being a climate-resilient carbon-neutral option for Portugal. Annual electricity unitary costs at final users (excluding taxes and levies) only increase up to 4% with climate change, but seasonal costs have higher variability. This analysis highlights that climate change affects the cost-optimal annual carbon-neutral power sector and needs to be included in energy planning.

1. Introduction

Renewable electricity is increasing worldwide and is expected to play a major role towards Paris Agreement's targets. Projections show an increase of 128% of renewable electricity between 2019 and 2030, meeting more than 52% of global power generation by 2030 [1]. Simultaneously, it is becoming evident that the deployment of renewable energy sources (RES) based technologies need to consider possible future climate impacts in power system operation since weather patterns and climate change significantly affect RES electricity supply and demand.

As reviewed by Yalew et al. [2], an increasing number of studies has been assessing climate change effects on different components of power systems, focusing on supply technologies, distribution infrastructures and also on the demand side. Several authors have evaluated how changing climate variables will affect energy supply (e.g., Cronin et al. [3] review), in particular individual RES *per se* and their direct impact on single electricity generation technologies, such as hydropower, wind, or solar photovoltaic (PV) (see Solaun and Cerdá [4] analysis on existing literature about climate change impacts on hydropower, wind, and solar technologies).

* Corresponding author. FCT/UNL DCEA, Campus de Caparica, 2829-516, Portugal.
** Corresponding author.
E-mail address: p.fs@fct.unl.pt (P. Fortes).

https://doi.org/10.1016/j.energy.2021.122106
0360-5442/